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ASSESSMENT OF SOIL QUALITY IN ORGANIC AND NON-ORGANIC PADDY FIELDS WITH TECHNICAL IRRIGATION SYSTEM IN SUSUKAN

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Abstract. Soil quality is a measure of the condition of soil. The goal of sustainable agriculture is to maintain a non-negative trend in productivity while maintaining soil quality. Susukan is an area in Semarang, Central Java, Indonesia, which has developed organic farming to increase rice productivity and quality. The main objective was to determine the sustainability of organic rice cropping systems. The organic farming system at the research location has been conducted for 8 years. Appropriate agricultural management can maintain the quality of soil, environment and improve the health of plants, animals and humans. This research aims to know the soil quality and determine the minimum data set (MDS) in organic and non-organic paddy field with a technical irrigation system. Paddy soil samples were analyzed in the laboratory. The parameters are porosity, permeability, hydrogen potential (pH), cation exchange capacity (CEC), soil organic matter (SOC), total-N (nitrogen), carbon/nitrogen (C/N) ratio, available-P (phosphorus), available-K (potassium), base saturation (BS), electric conductivity (EC), soil respiration (qCO_2), redox potential (Eh) with 3 repetitions. The value of soil quality index (SQI) in the organic paddy field is 3.216 with bad soil quality criteria, while the non-organic paddy field is 0.147 with very bad criteria. The soil quality values are based on the key factors or MDS that is potential redox (EH), soil respiration (qCO_2), potential hydrogen (pH), porosity, soil organic matter (SOC), total-N (nitrogen), C/N ratio, available-P (phosphorus).

Keywords: soil quality, paddy fields, principal component analysis, minimum data set (MDS), soil quality index (SQI)

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INTRODUCTION

Many activities occur in the soil and on the ground indicating that the soil is very important for life. Increased agricultural, fishery and livestock activities to meet the needs of life, cause contamination of water, air, and soil. Soil contamination can be shown with good or bad quality of the soil. Good soil quality will maintain the production of food, ecosystems, environment and human health (Doran and Parkin 1994). According to Plaster (2003), soil quality is the capacity of a soil to provide the functions needed by humans and natural ecosystems for a long time. The soil quality combines physical, chemical and biological properties. Each property shows the function of the soil based on its type, land use, climate (Ditzler and Tugel 2002). Evaluation of soil quality combining physical (fill weight, porosity, permeability, root depth, infiltration water rate, water holding capacity, and aggregate stability), chemical (pH, electrical conductivity, cation exchange capacity, organic matter, N, K and Ca can be exchanged) and biological (Cmic, Nmic, worms, enzyme, pest and soil microbial respiration) properties can be used as an indicator of land health. The properties can also be determined as minimum data set (MDS) that can be used as a quantitative indicator in determining soil quality (Dang 2007). Based on Bachmann and Kinzel (1992), the MDS was obtained from the correlation test using software. On the basis of MDS, we can also determine the soil quality index. MDS is a very influential indicator of soil quality testing (Larson and Pierce 1991).

Paddy is the predominant crop in Indonesia. Its productivity is influenced by soil characteristics and irrigation system. Bad soil characteristics, poor nutrition, low cation exchange capacity, high Fe/Al cations can decrease rice productivity (Haefele *et al*. 2014). Rice production in 2016 reached 79.141 billion kg per year or up 4.96% compared to 2015 (Badan Pusat Statistik 2017). To maintain rice productivity, efforts should be made. According to Andoko (2008), we can do organic farming. Such kind of farming enhances sustainable rice production by improving soil fertility using natural resources such as recycling agricultural waste (Sutanto 2002). Organic farming avoids chemical fertilizers, pesticides and herbicides. Fertilizing and eliminating pests and weeds is done organically and naturally (Willer *et al*. 2008). Paddy is grown on paddy fields. According to Waluyaningsih (2008), the paddy field is a submerged land with intensive management. Paddy fields also can support plant growth and they are resistant to soil degradation. According to Fadjar (2013), the determinants of productivity in the paddy fields refer to the availability of water. Irrigation aims to improve water use efficiency. Today, we know some irrigation systems were technical irrigation, semi-technical and conventional irrigation. A technical irrigation system is an effective and efficient type of irrigation (Kertasapoetra 1994).

Intensive management of paddy fields without preservation of soil fertility causes degradation of soil properties (biology, physics, chemistry) (Sembiring and Abdulrachman 2008). This causes that paddy productivity is not optimal. Ketapang is an area in which organic farming is provided. Wrong management systems cause a decrease in land productivity. This indicates that the land does not work properly. Land that is not functioning properly will degrade soil quality. This research aims to examine the soil quality and determine the minimum data set in organic and non-organic paddy fields with the technical irrigation system.

MATERIALS AND METHODS

Study site

The research was conducted at organic and non-organic paddy fields with technical irrigation in the Ketapang village, Susukan District, Semarang city, Central Java, Indonesia. The location is always submerged. The organic farming system at the research location has been implemented for 8 years. The Ketapang village is at latitude 7°40'9"S and longitude 110°60'48"E and has an altitude of 495–600 m above sea level. The soil type in the Ketapang village is brown andosol and reddish-brown latosol. The location has low lime content. The slope is between 8 and 13%.

Experiment layout

The research has been done from July to August 2017. It was conducted by using the field survey method by measuring, identification, enumeration and direct testing in the field. The sample was taken from organic and non-organic paddy fields. The paddy soil sample was taken for physical, biological, chemical analysis in a laboratory. It consists of 10 composite samples of organic paddy fields and 10 samples of non-organic paddy fields at a depth of 0–30 cm (surface). Soil sampling is collected by purposive sampling. There was also conducted analysis of vegetation using a single plot method. The method included putting the rope on 1 × 1 m plot, then the vegetation and, finally, the diversity of vegetation was calculated. The diversity of soil fauna was examined by using a pitfall trap and monolith method. To the pitfall trap diluted detergent was added. Then it was poured into a plastic cup and left for 24 hours. The monolith method creates a cube of side 20 × 20 × 20 cm to get the soil samples. Then the soil sample is lifted and counted. The tools used for field analysis are: maps, Global Positioning System (GPS), drill and clinometer, whereas the materials include pH sticks, aquadest, potassium chloride, hydrogen peroxide (H_2O_2), potassium thiocyanate, hydrochloric acid (HCl 1,2 N), hydrochloric acid (HCl 2 N).

Samples of paddy fields were tagged, air dried, sieved using 2-mm and 0.5-mm sieves, and then stored for laboratory analysis. There were measured different parameters: porosity – by using ratio bulk density and particle density methods (Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture 2006), permeability – by using constant head permeameter method (Indonesian Agency…), hydrogen potential (pH) – using soil:water suspension (1:5; w/v) method (Indonesian Soil Research Institue 2009), cation exchange capacity (CEC) – by using 1 N ammonium acetate extraction method (Indonesian Soil…), soil organic carbon (SOC) – by using Walkey and Black method (Indonesian Soil…), total-N using the Kjeldahl method (Indonesian Soil…), carbon/nitrogen ratio (C/N ratio) – by using comparison between C organic soil and total N of soil (Indonesian Soil…), available-P – by using the Olsen method (Indonesian Soil…), available-K – by using 1 N ammonium acetate extraction method (Indonesian Soil…), base saturation (BS) – by determining the proportion of the CEC occupied by basic cations metod (Indonesian Soil…), electric conductivity (EC) – by using the soil:water suspension (1:5; w/v) method (Indonesian Soil…), soil respiration (qCO_2) – by using the titrimetric method (Anas 1989), redox potential (Eh) – by using using the soil:water suspension (1:5; w/v) method (Indonesian Soil…). All the soil analysis were replicated 3 times.

Statistical analysis

The data of soil analysis were tested with the Pearson correlation analysis with the 5% (α 0.05) confidence level, and principal component analysis (PCA) with using Minitab 18 software. Pearson correlation was used to know the variables relating to each other and principal component analysis – to know the main indicator. Assessment of soil quality can be done by calculating the soil quality index with scoring selected variables from PCA. Soil quality was calculated using the following equation:

$$\mathbf{IKT} = \sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{Wi\ x\ Si}$$

Where:
SQI – soil quality index
Si – score index
Wi – weight index
n – number of indicator

The value of soil quality index ranges from 0 to 0.9. Based on the value, we can determine the quality of the soil, i.e. soil quality class by Cantú *et al.* (2007) (Table 1).

Table 1. Soil quality indexing class by Cantú *et al.* (2007)

Soil quality	Range	Class
Very good	0.80–1	1
Good	0.60–0.79	2
Middle	0.35–0.59	3
Low	0.20–0.34	4
Very low	0–0.19	5

RESULTS AND DISCUSSION

The results of field analysis show that the predominant vegetation in the non-organic paddy field is paddy (100%), and the predominant vegetation in the organic paddy field is paddy (90%) and weeds (10%). The function of weeds or vegetations is to reduce surface flow and increase infiltration (Dabney *et al*. 2001). Rainwater will permeate the soil. If water absorption increases, water storage in the soil increase too (Joyce *et al*. 2002). Soil fauna performs a complex function in the soil. It is not found in non-organic paddy fields, but in the organic ones. There are found small frogs, worms, eels, black and red ants, crickets, and mangas. Soil fauna has an important role in decomposition. It can change dead organic substances into organic matter and then obtain energy (Direktorat Penyiapan Pengusahaan Hutan 1989). Average results of laboratory analysis were based on the criteria of Wander *et al.* (2002) and Indonesian Soil Research Institute (2009) (Table 2).

Table 2. Results of laboratory analysis that has been average based on criteria of Wander *et al.* (2002) and Indonesian Soil Research Institute (2009)

Parameters	Organic	Non-organic
Porosity (%)	16.82^{L}	11.25^{VL}
Permeability (cm/hour)	0.33^{S}	0.3^{S}
Potential hydrogen (pH)	6.74^{N}	6.47^{MA}
Cation exchange capacity (CEC) (me/100 kg)	34.13^{H}	25.1^{H}
Soil organic carbon (SOC) (%)	2.07^{M}	0.55^{VL}
Total-Nitrogen (N) (%)	0.3^{M}	0.26^{M}
Carbon/Nitrogen (C/N) ratio (%)	0.21^{VL}	0.49^{VL}
Available-phosphorus (P) (mg/kg)	10.9^{M}	21.06^{VH}
Available-potassium (K) (mg/kg)	0.68^{H}	0.7^{H}
Base saturation (BS) (%)	23.5^{L}	32^{L}
Electric conductivity (EC) (dS/m)	0.63^{VL}	0.7^{VL}
Soil respiration (qCO_2) (mg/day)	0.43^{I}	0.2^{I}
Redox potential (EH) (mV)	238.9^{LR}	135.5^{MR}

Note: VL – very low; L – low; M – medium; H – high; VH – very high; S – slow; F – fast; MA – medium acid; N – neutral; I – ideal; LR – low reduction; MR – medium reduction

Based on the criteria of Wander *et al.* (2002), soil porosity in the organic farming system is low (16.82%) and in the non-organic farming system – very low (11.25%). Porosity is a total of air space in units of soil volume in the water and the air. Total pore space of soil in the paddy field at a depth of 0–10 and 10–20 decreases in line with the increase of time of paddy field management. Subagyono *et al.* (2003) reported that the soil puddling decreases the porosity of the soil with sandy-silt-loam and sandy-clay-loam textures.

Based on the criteria of Balai Besar Litbang Sumberdaya Lahan Pertanian Indonesia (2006), organic and non-organic paddy fields have slow permeability (0.33 cm/hour and 0.3 cm/hour, respectively). Soil pore is a factor affecting soil permeability. The soil which has large macropores is characterized by a high permeability coefficient value, because the ability of water to flow through the macropores is higher (Rohmat and Indratmo 2006).

The pH will affect soil processes, such as the decomposition of organic matter, minerals, clay mineral formation, and the availability of nutrients (Roesmarkam and Yuwono 2002). H_2O, pH and actual pH were analyzed by an electrometric method then classified by the criteria of Balittan. Samples for the organic paddy field showed neutral acid (6.74) and for the non-organic – medium acid (6.47). Neutral and medium acid is caused by the immersion factor. Soil type in the research location is andosol. According to Wirjodihardjo *et al.* (1963), pH of andosol is between 4.5 and 5 (acid). Acid soil is submerged, and there will be reduction of Fe^{3-} to Fe^{2+}. Fe reduction occurs during OH^- release and H^+ consumption. This reaction causes the pH of andosol to medium acid and neutral.

CEC analysis was based on the criteria of Indonesian Soil Research Institute (2009), both organic and non-organic farming systems showed high values (34.13 me/100Kg and 25.1 me/100Kg). High CEC values are caused by high clay content, and vegetation (C/N ratio <5). CEC also increases due to the pH charge (Foth 1984). The CEC value at the research location also came from the Si-OH dissociation. The reaction occurs because the pH increases, so the hydroxyl concentration becomes high and continues to increase. The cation exchange capacity in tropical soils also depends on soil pH, since it consists of permanent charge and pH dependent charge.

The analysis and classification of soil organic carbon based on the Indonesian Soil Research Institute (2009) was medium (2.07%) for organic and very low (0.55%) for non-organic. The application of organic farming system means that soil organic carbon in the organic paddy field is higher. But in all locations, the value of soil organic carbon is not high. The location has a high slope (>8%), so that the soil organic matter is carried by surface water flow. Grass and straw found in the paddy fields are often used for livestock feed, so paddy fields vegetation is no longer possible. Sources of organic matter only come from organic fertilizers. Supriyadi (2008) reported that soil organic carbon is influenced by several factors such as temperature, soil reaction, organic matter input (vegetation, soil microorganism, animal).

Total-N on all samples was at the medium level, the source of N in the soil comes from the atmosphere, fertilizer and decomposition of soil organic matter. The total-N value is medium, because the source of N only comes from organic fertilizers. Most of the nitrogen held in the soil is lost through runoff, volatilization and leaching. Based on Stangel *et al.* (1985) and Rochayati *et al.* (1990), volatilization reaches 70% and depends on soil CEC and high immersion. High nitrogen losses means that only 10% of the nitrogen is absorbed by plants. The addition of total-N to the soil can be done by adding a slow-release fertilizer, such as providing paddy straw after harvesting to the paddy field.

C/N (carbon/nitrogen) ratio is a measure to show the quality of soil organic matter, such as plant and animal residues. Based on the C/N ratio criteria of Indonesian Soil Research Institute (2009), organic and non-organic paddy fields have very low C/N ratios (0.21% and 0.49%, respectively). Purwanto *et al*. (2014) reported that a good organic matter has a C/N ratio at the level of <25. Thus, it can be said that the quality of the organic matter at all location and the rate of decomposition is good. Good quality organic matter will quickly release nutrients for plants.

The available-P level was analyzed using the Olsen method, the result of analysis was medium (10.9 mg/kg) on the organic paddy field, and very high on the non-organic paddy field (21.06 ppm). Phosphorus is available because pH at the research location is medium acid (6.47) to neutral (6.74), where in pH 6–7, P can be available for plants and not absorbed by Al (Purwanto *et al*. 2014). Available-P in the non-organic paddy field is very high due to high chemical fertilizer input.

The amount of K content in the soil is because the potassium nutrient in the soil is more stable than the nitrogen element, and due to faster mobility compared to phosphorus nutrient; the availability of K in the soil is influenced by soil mineralogy (Hardjowigeno 2002). The soil type at the research location was andisol. The average height is 500–600 m above sea level which allows us to have a 2:1 mineral type. The source of potassium in the soil will be tied (fixed) into the mineral lattices, so that it becomes slow or less available. Potassium in this form cannot be replaced with nutrient exchanges, so potassium is not available (Nuraini 2008). The available-K in case of all samples have a high category. This is caused by the input of organic matter in organic paddy fields. Immersion process can also cause available-K to be high. Immersion causes the pH to be neutral and stable. At neutral pH, N, P and K are also available (Hartati *et al*. 2013).

The base saturation value (BS) of the soil is the percentage of total CEC occupied by the particular nutrients (Ca, Mg, Na, and K) (Damanik *et al*. 2010). The base saturation value (BS) of all samples was low. One of the factors which influences the value of BS is the value of soil pH. pH at the research location is neutral. Matching with Sudaryono's statement, low pH has low base saturation, while high pH has high base saturation.

Electric conductivity (EC) is the amount of salt in water. Water with high salt content (Na, Mg, K and Ca) will have high EC (Sudaryono 2009). The results of the analysis showed that the EC value in all samples is very low (<1 dS/m). According to Aini *et al*. (2014), in normal submerged soils, the highest EC value is between 2 and 4 dS/m.

Soil respiration is the process that releases carbon from the soil to the atmosphere in the form of CO_2, generated by soil microorganisms and plant roots. It is influenced by biological factors (vegetation, microorganisms) and environmental factors (temperature, humidity, pH), but to a large extent, by man-made factors (Aini *et al*. 2014). The result showed that the respiration of the organic paddy field was 0.43 or ideal, while of the non-organic paddy field it was 0.2 or medium. The variety and quantity of vegetation in the study sites led to the large number of plant roots that emit CO_2 gas and to root exudates. Root exudates and organic matter constitute the energy source of microorganisms, so that land with many and varied vegetation can increase the number of microorganisms and soil respiration.

The results of the redox potential (Eh) analysis of organic paddy field values was low reduction (238.9), and in the case of non-organic paddy soil, it was a medium reduction (135.5). According to Yoshida *et al*. (1972), this is due to the change of Fe^{+3} to Fe^{+2} caused by the change of oxidative situation to the reductive one. The reaction is influenced by the soil microbial activity that stimulates the reduction process of Fe^{+3} to Fe^{+2}, increases pH and decreases Eh.

Soil quality index (SQI)

Physical, chemical and biological indicators are related to each other. The relationship between each of these indicators can be explained statistically using correlation analysis (Table 3). This correlation analysis used a level of 5% (α 0.05), two indicators were said to have a strong correlation with the Pearson correlation value closer to 1or | -1 | or with a *p*-value less than α (0.05 or 5%). Based on the analysis, there are indicators with a strong correlation. The correlation occurs between porosity and soil organic carbon, porosity with total-N, total-N with permeability, C/N ratio with soil organic carbon, EC with soil organic carbon, pH with soil respiration (qCO_2), C/N ratio with available-P, C/N ratio with Eh and Eh with available-K. A positive correlation means that both indicators increase in value, when one indicator rises. The result of the correlation analysis showed that porosity and soil organic carbon has a positive correlation ($r = 0.707$). Permeability is influenced by organic matter content, if the amount of soil organic matter is low then soil permeability becomes low. Another variable that has a positive correlation is porosity and total-N ($r = 0.740$). Porosity contributes to N leaching in the soil. Permeability and total-N also have a positive correlation value that is r = 0.718. If the permeability is low then the possibility of N leached inside the soil is also lower. Soil respiration and pH have a correlation value r = 0.577. Soil respiration is a description of the total CO_2 released by soil microorganisms. Microorganisms have different pH tolerance levels. Positive correlations also occur in the C/N ratio and P is available (r = 0.885). Low C/N ratio will accelerate the availability of nutrients for plant absorption, including P. Correlation with a negative value means that the value of the two correlated indicators moves the opposite, increasing the value of one indicator will decrease the value of another indicator. The analysis showed a negative correlation on the variable soil organic carbon with a C/N ratio (r = -0.778). Negative correlations also occur in the soil organic carbon with EC (r = -0.635). Eh and C/N ratio also have negative correlation (r = 0.743). High C-organic, causes low Eh – Eh with available-P too (r = -0.749). Redox reactions affected the availability of P.

Table 3. Result correlation analysis between variables

	Porosity	Permeability	pH	C-organic	C/N ratio	N-total	Available-P	BS	EC	Eh	qCO_2
Permeability	0.514										
pH	-0.328	0.363									
C-organic	0.678*	0.391	-0.118								
C/N ratio	0.455	0.045	-0.282	0.884*							
N-total	0.746	0.617*	0.126	0.516	0.09						
Available-P	-0.417	0.454	0.689*	-0.399	-0.649*	0.115					
BS	0.233	0.371	0.366	0.052	-0.129	0.392	0.247				
EC	-0.394	-0.153	-0.029	-0.645*	-0.512	-0.473	0.28	0.196			
Eh	0.083	-0.307	0.202	0.06	0.156	0.052	-0.428	0.387	-0.137		
qCO_2	-0.116	0.026	0.511	0.126	0.142	-0.067	0.082	0.537	-0.077	0.373	
Available-K	-0.253	-0.162	0.161	-0.197	-0.142	-0.16	0.104	0.468	0.297	0.388	0.197

The soil index was determined using principal component analysis (PCA). The result of principal component analysis (PCA) is a minimum data set (MDS) of soil quality, which is the smallest data set to represent all values of soil quality. PC used as MDS is PC with eigenvalue ≥1. MDS is necessary to calculate the soil quality index is obtained by determining the indicator with the highest value on each PC (PC1 to PC4) (Table 4). The indicators with the highest values on PC1 to PC4 are porosity, SOC, total N, pH, Eh, C/N-ratio, available-P, and

qCO_2. Then, the value of the selected indicator on the PC is multiplied by the scores of each selected indicator to determine the value of soil quality. Scoring of soil quality was based on Wander *et al.* (2002) and the Indonesian Soil Research Institute (2009). The results obtained from the calculation of the soil quality index, were then categorized. The soil quality class is divided into very good, good, medium, low and very low (Table 5).

Table 4. The results of MDS by PCA

Eigenvalue	4.5128	2.5865	2.0182	1.0271	0.6410	0.5913
Proportion	0.376	0.216	0.168	0.086	0.053	0.049
Cumulative	0.376	0.592	0.760	0.845	0.899	0.948
Variable	PC1	PC2	PC3	PC4		
Porosity	0.391*	-0.238	0.082*	-0.266		
Permeability	0.160	-0.362	-0.442	-0.202		
pH	0.066	0.195*	-0.634	0.156*		
Soil Organic Matter	0.425*	-0.063	0.022*	-0.039		
Total-N	0.270*	-0.395	-0.246	-0.078		
C/Nratio	-0.392	-0.278	-0.028	0.201*		
Available-P	-0.316	-0.334	-0.226	0.339*		
Available-K	-0.221	0.282	-0.140	-0.325		
BS	-0.212	0.044	-0.398	-0.482		
EC	-0.326	0.175	-0.038	-0.322		
qCO_2	0.187	0.352*	-0.317	0.502*		
EH	0.274	0.436*	-0.048	-0.087		

Note: pH – potential hydrogen; SOC – soil organic carbon; Total-N – total nitrogen; Carbon/Nitrogen – C/N ratio; available-P (phosphorus); available-K (potassium); BS – base saturation; EC – electric conductivity; qCO_2 – soil respiration; EH – redox potential

Table 5.The soil quality value of organic paddy field and non-organic paddy fields

No.	MDS	Wi	Organic	Non-organic
			Si	
1	Porosity	0.155251	2	1
2	SOC	0.155251	1	1
3	Total N	0.155251	2	2
4	pH	0.184932	4	4
5	qCO_2	0.184932	4	4
6	EH	0.184932	4	3
7	C/Nratio	0.07363	1	1
8	Available-P	0.07363	2	2
	SQI		3.216	0.147
	Score		4	5
	Class		Low	Very Low

Note: MDS – minimum data set; Si – soil index;Wi – weight index

The calculation results of soil quality index were then normalized by dividing 10 to be classified according to Cantú *et al.* (2007). The value of soil quality in organic paddy field with technical irrigation was 3.216 (bad), while the quality of soil in non-organic paddy field with technical irrigation system was 0.147 (very bad). This showed that the quality of organic paddy field is better than that of the non-organic paddy field, but in the second research location there were no good soil quality criteria observed. This showed that organic farming that has been provided for 8 years has not significantly affected the improvement of paddy field quality. Soil quality indexes provided in Fig. 1.

Puddling causes changes in soil physical properties, one of which is porosity. Puddling closes the pore space in the soil layer. This condition accelerates the formation of steel tread layer (plowpan), so that the porosity and distribution of pore spaces are disturbed and permeability was slow. Good soils have macropore and micropore balanced (Yoshida *et al*. 1972).

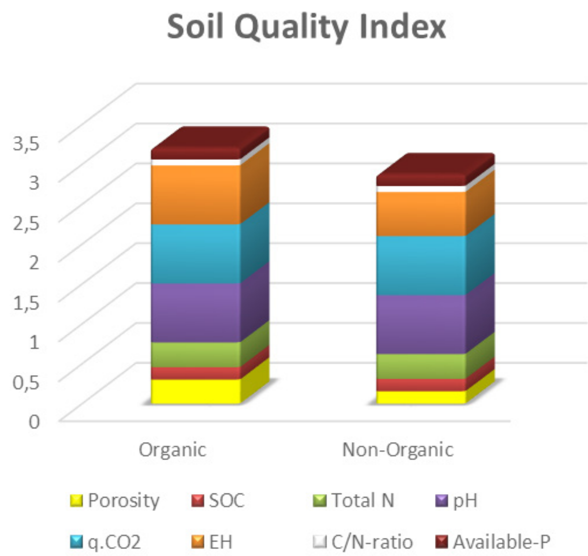

Fig. 1. Soil quality index in organic and non-organic paddy fields

Note: SOC – soil organic matter; Total-N – total nitrogen; pH – potential hydrogen; qCO_2 – soil respiration; EH – potential redox; C/N – carbon/nitrogen ratio; available-P (phosphorus)

Available-N in submerged soil was higher than in non-submerged soil. N increases with higher levels of nitrogen, pH and soil temperature. Most of nitrogen in the soil was in the organic form, such as organic matter or N fixation due to soil microbes and small parts were forms of inorganic nitrogen (NH^{4+}, NO^{3-}, NO_{2-}). In submerged soil, N is an unstable nutrient due to the mineralization process of organic matter (ammonification, denitrification, nitrification) by microbes (Diah and Abdulrachman 2009).

The increase in pH value is due to the contribution of organic material that releases OH ions from the reduction process. Under these conditions, the acid pH increased to 6.5 with the addition of organic matter. The reduced Fe^{+3} ions change to Fe^{+2}, thus releasing OH ions. This condition can increase the soil pH, because there is a balance between H^+ ions with OH ions. The pH increases with the increase of immersion height, and increases with the presence of organic matter. On the contrary, Eh decreases with increasing the height of the immersion, and further decreases with the addition of organic matter. The change is due to the contribution of organic matter to the soil solution. Hydroxyl groups and other carboxyl compounds can provide balance to the activity of H^+ ions. This causes a decrease in the concentration of H^+ ions. The decrease leads to a decrease in the number of electrons in the soil solution. The number of electrons is proportional to the redox potential, so decreasing the number of electrons will automatically decrease the value of Eh (Reddy and Patrick 1986).

Organic material in organic and non-organic paddy field was low, this makes that rice fields are open areas and vegetation is not diverse (Endale 2016). The high total soil organic carbon is important for sustainability since it influences the soil quality. Organic matter in the mineralization process will release complete nutrients (N, P, K, Ca, Mg, S, as well as micronutrients in an unspecified amount). According to Fahriansyah *et al.* (2015), the addition of organic matter has an effect on the availability of K. Based on the results of soil analysis, the level of available-K in organic and non-organic paddy field in the Ketapang village was high or very high. The function of potassium is cell development and osmotic pressure regulation. Available-K was large, causing osmotic pressure inside and outside the cells to be more balanced (Agus and Subiksa 2007).

Available soil phosphorus is phosphorus soluble in water and citric acid. The P in the soil can be distinguished by its solubility and availability in the soil. Phosphorus that is soluble in water is P that can be absorbed by plants. The availability of P in the soil is affected by pH, Fe, Al, Mn soluble ions, whereas the availability of Ca – by the amount and degree of decomposition of organic matter. Acidity (pH), soil organic matter, and parent materials affect the availability of P in the soil (Kuswandi 1993). The availability of P is also caused by the condition of submerged land. Paddy soil is an intensely submerged land (Stevenson and Cole 1999). This immersion causes the pH to be neutral and stable, this may affect the availability of P. According to Dang (2007), P is available at pH 6–7. The application of organic farming affects the availability of P due to the release of phosphorus from Fe-P binding. Organic acids form chelates with Al and Fe, and release phosphates in soil solution.

Soil respiration refers to the activity of soil microorganisms. One way to know the activity of all microorganisms in the soil is to calculate the carbon dioxide (CO_2) released by the soil organism during a certain time. The result showed that the respiration of the organic paddy field was 0.43 or ideal, while in case of the non-organic paddy field it was 0.2 or medium. In case of soil containing water up to 80%, soil respiration decreases to a minimum. Most aerobic microorganisms use NO_3, so it causes losses of nitrogen gas (United States Department Agriculture 2012). This was indicated by the results of soil analysis of total-N. According to Iswandi *et al.* (1995), soil microorganisms are influenced by several factors: adequate nutrients, soil pH, aerase and drainage, and sources of energy or organic matter. In the organic and non-organic paddy fields, their moisture, pH, aeration and drainage are at the same level. The difference refers to the fertilizer or input into the soil. Organic paddy fields use organic fertilizers and mechanical pest control, while non-organic paddy fields use chemical fertilizers, herbicides and pesticides. What is more, organic matter is an energy source that is necessary for soil microorganisms for decomposition (Susilawati 2013).

CONCLUSIONS

The value of SQI in the organic paddy field is 3.216 (class 4) with bad soil quality criteria, while in case of the non-organic paddy field, the value is 0.147 (class 5) with very bad criteria. This shows that organic farming that has been running for 8 years has not significantly affected the improvement of paddy field quality. The soil quality values are based on the key factors or minimum data set (MDS) that is potential redox (Eh), soil respiration (qCO_2), potential hydrogen (pH), porosity, soil organic matter (SOC), total-N (nitrogen), C/N (carbon/nitrogen) ratio, available-P (phosphorus).

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